Climate-Based Issues and Tools Behind NOAA's Seasonal Hurricane Outlooks

By

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CPC outlooks made in collaboration with
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Hurricane Research Division/ OAR
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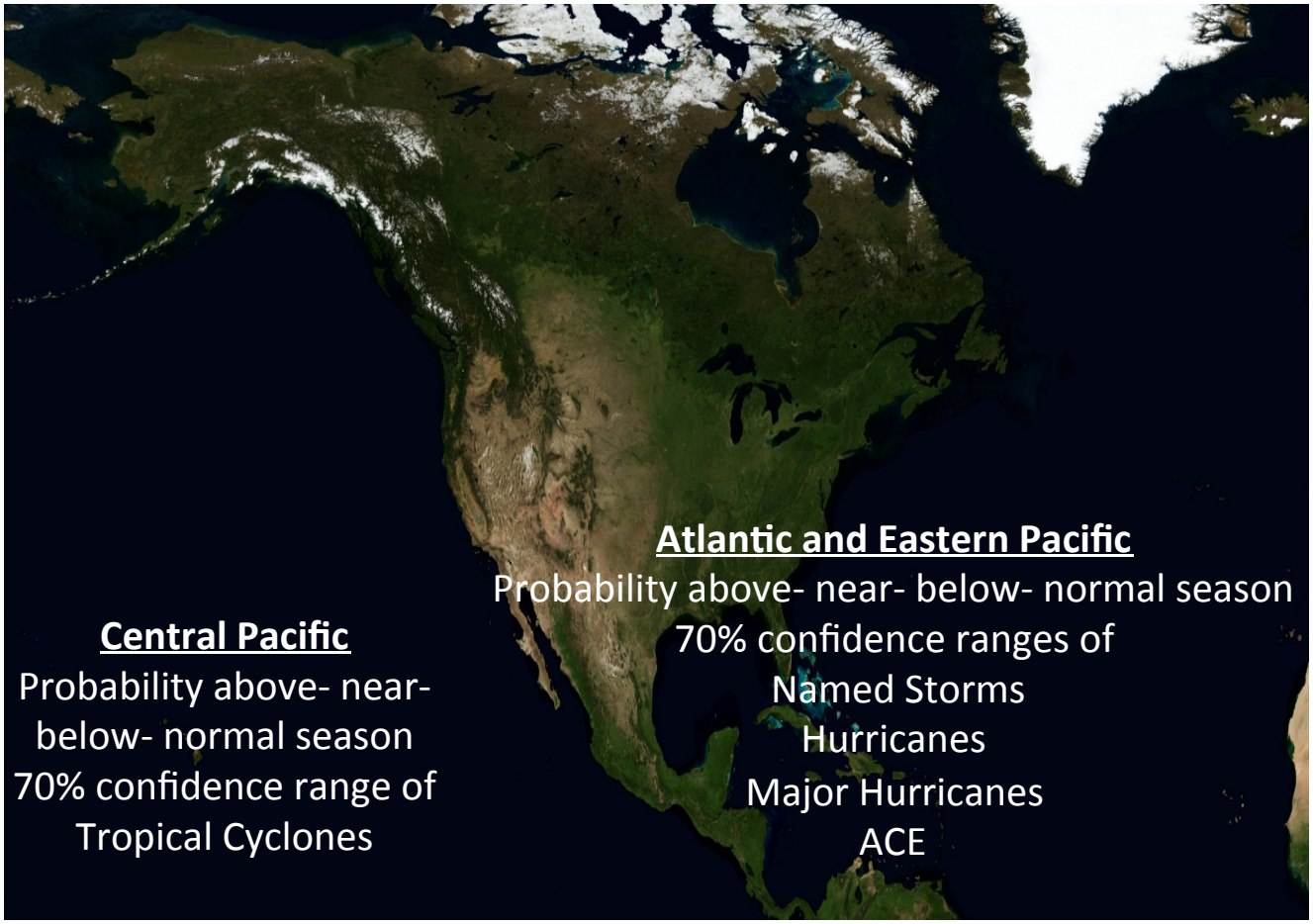
Atlantic basin outlook and monitoring:
www.cpc.ncep.noaa.gov/products/hurricane/

Nature of NOAA's Seasonal Hurricane Outlooks



- Outlooks are probabilistic guide to overall seasonal activity
- Not a seasonal hurricane landfall prediction.
- Do not predict levels of activity for any particular region.

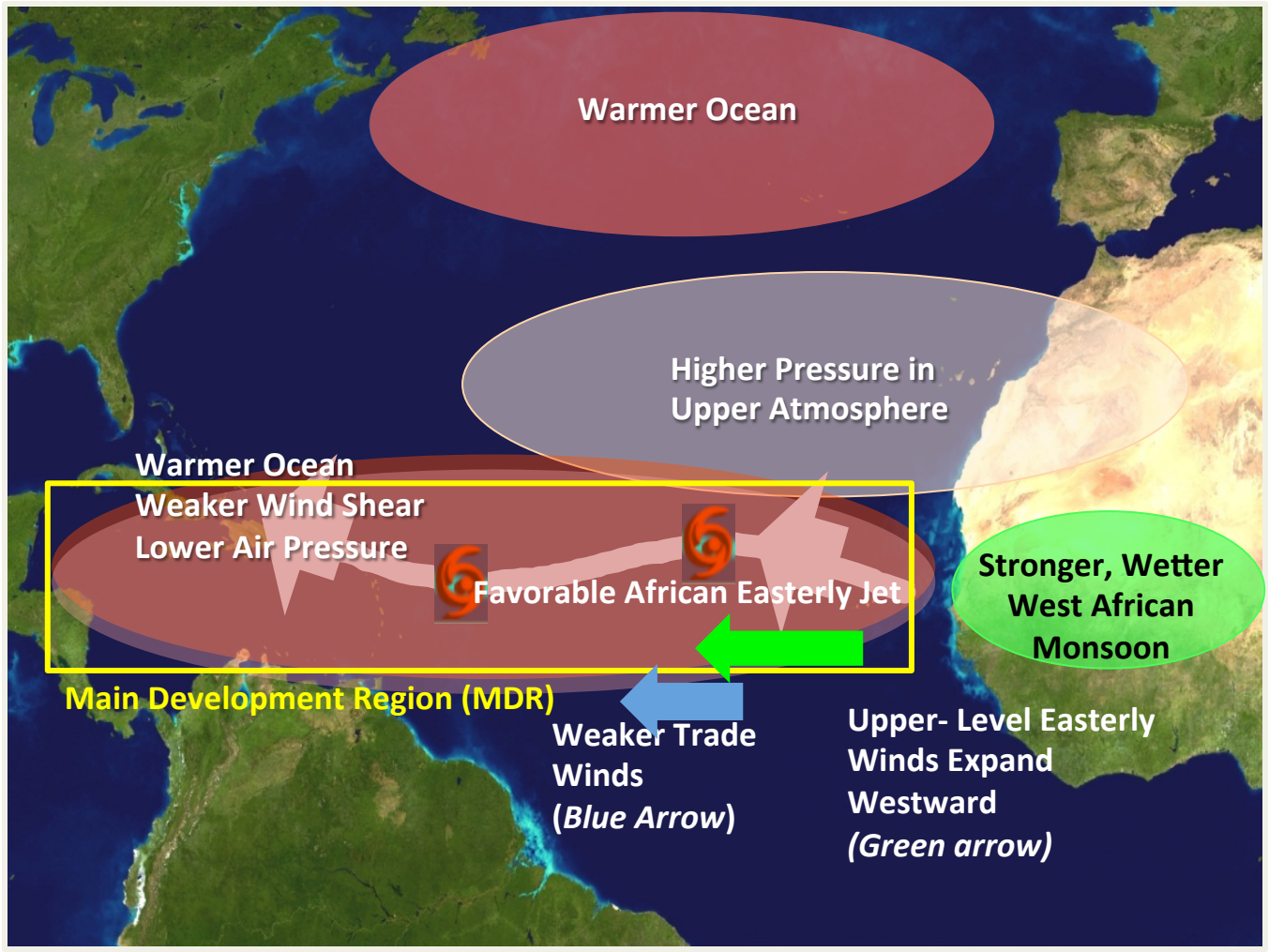
How the Atlantic Outlook is Issued

•Atlantic pre-season outlook: issued in late May with national press conference, press release, technical write-up

•Updated Atlantic outlook: issued in early August (coincide with peak of season Aug-Oct)- with press teleconference, press release, technical write-up

•Technical write-ups convey the outlook, the forecast confidence/ uncertainty, and the science behind the outlook.

Conditions During Atlantic High-Activity Era



High- and low-activity decades and seasons often result from an inter-related set of conditions across the Main Development Region.

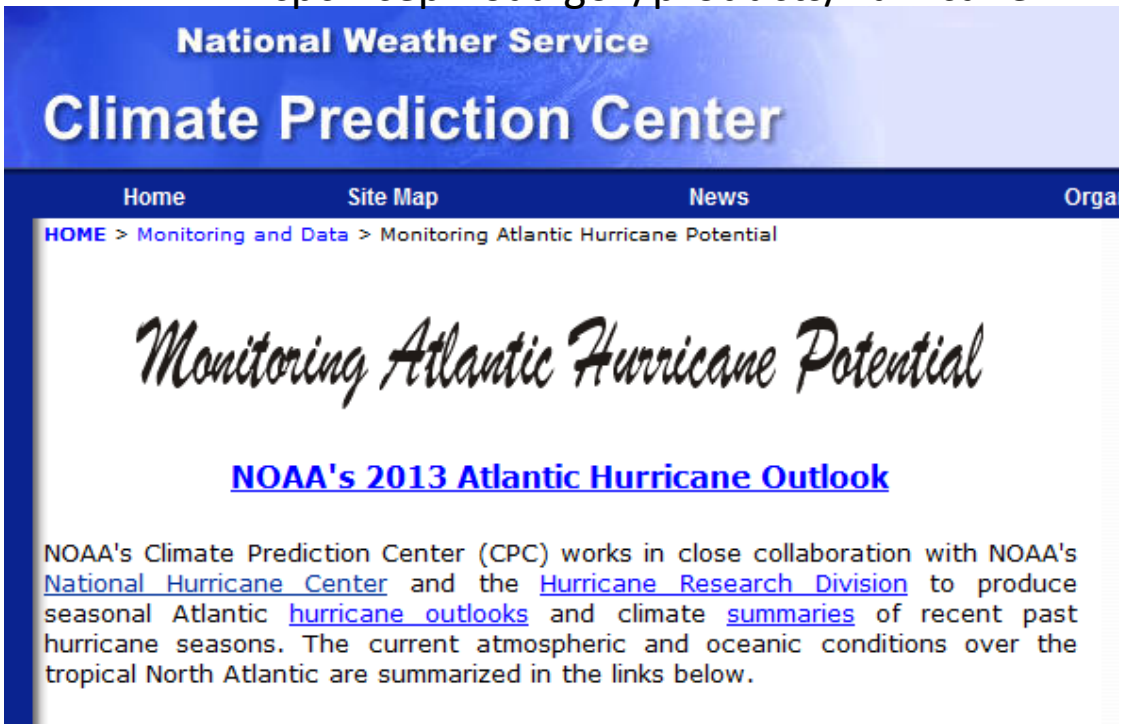
Atlantic Outlook: Three Main Climate Predictors

Regional atmospheric and oceanic conditions that ultimately determine the seasonal hurricane activity are strongly influenced and predicted by three main climate factors.

- Atlantic Multi-decadal Oscillation (AMO)- multi-decadal fluctuations in Atlantic hurricane activity
- ENSO: interannual fluctuations in Atlantic hurricane activity
- Tropical Atlantic SST anomalies

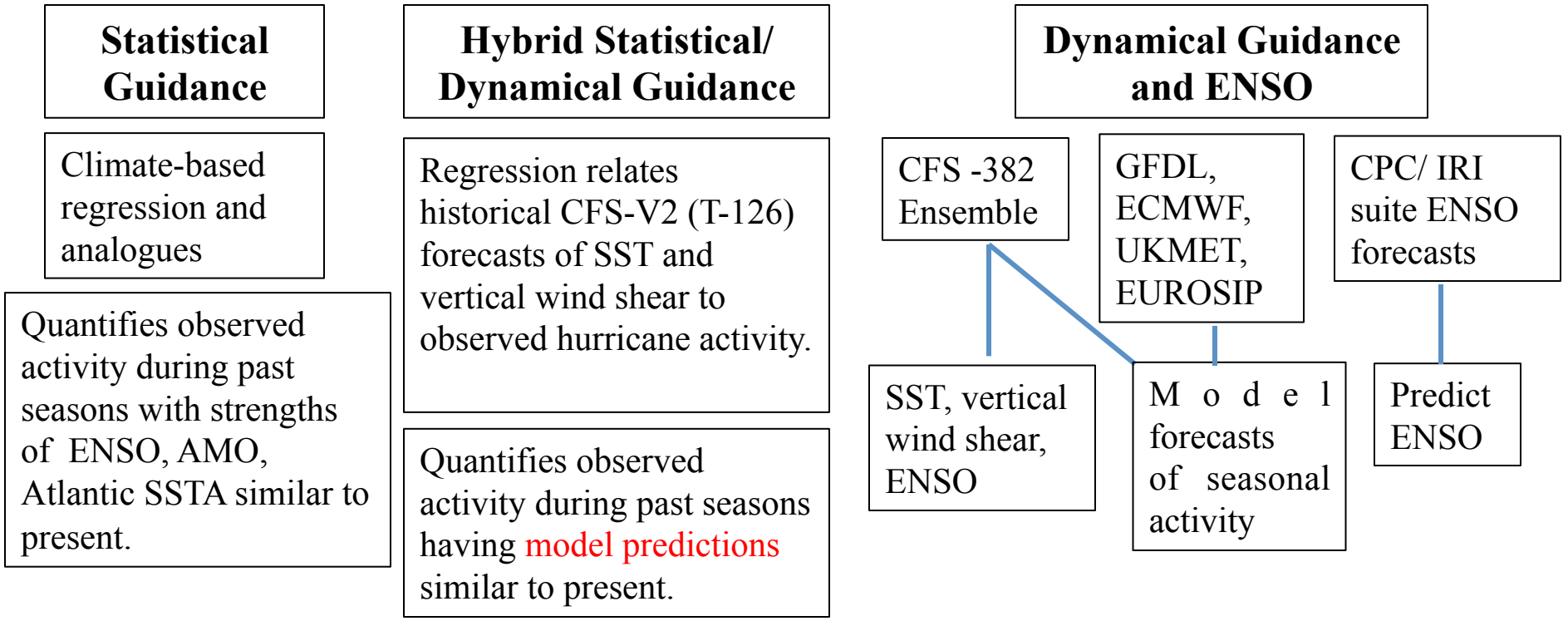
Extensive Monitoring and Analysis Support the Outlooks

www.cpc.ncep.noaa.gov/products/hurricane



- Current and recent (last 60 days) conditions for monitoring climate patterns and key local circulation features
- GFS Model forecasts of key circulation features
- Archive of seasonal outlooks
- Seasonal climate summaries assess climate patterns and local conditions

NOAA's Atlantic Hurricane Season Outlook Process



Forecast tool consensus guidance provides 70% probability ranges of activity

Forecast team members each predict 70% probability ranges of activity.

Final outlook is consensus of individual forecaster predicted ranges.

Regression: Establish Your Statistical Predictors

Predictors must be independent, predictable, and explain large amounts of variance when combined.

Issues You Will Likely Encounter

- **Ensuring that your predictors are independent**
  * Climate factors (ENSO, AMO) produce strong coherent variability of local conditions.
  * Local predictors may not provide additional predictability

- **Ensuring that your predictors are predictable**
  *Only predictors that are predictable in real time can help your forecast: NAO?
  *Predictability varies during the year: ENSO

- **Explained variance: Know amount of variance NOT explained by the predictors**
  *Statistically significant correlation of 0.5 means that 25% of the variance is being explained. BUT!!! 75% of the signal you are trying to predict is NOT being explained.

- **Effectively conveying forecast guidance results to your team**

- **Understanding error inherent in your forecast tools**

- **Developing tools to deal with combined climate impacts**

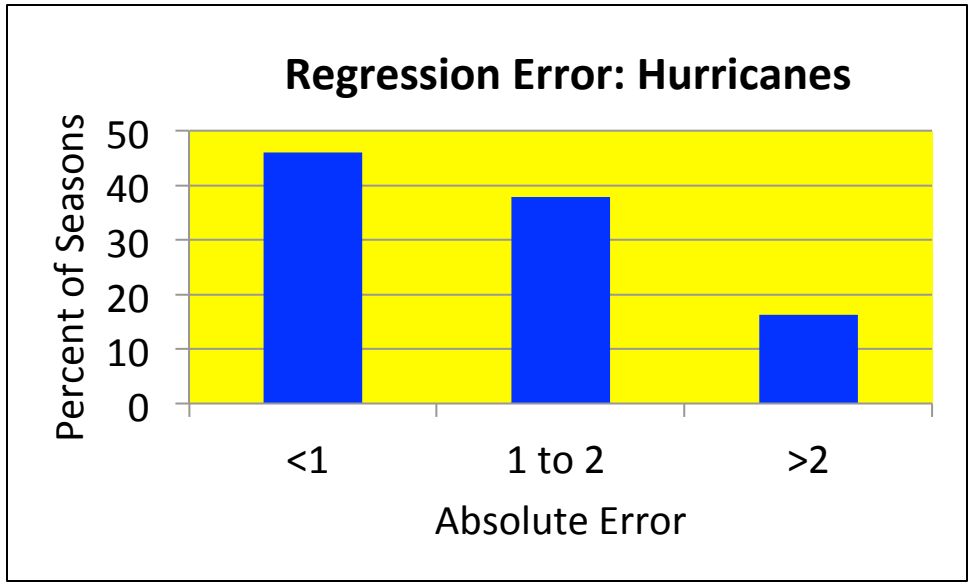
Convey Guidance Results Effectively To Forecast Team

Regression results in tabular form allows forecasters to easily see likely ranges of predicted activity for various levels of uncertainty in the climate prediction.

Multiple Linear Regression Guidance for Seasonal Atlantic Hurricanes

		Tropical Atlantic SST Anomalies (°C)					
		-0.5°C	**-0.25°C**	**0°C**	**0.25°C**	**0.5°C**	**0.75°C**
	Strong	2.3	3.4	4.4	5.5	6.6	7.7
El Niño	**Moderate**	3.0	4.1	5.2	6.3	7.3	8.4
	Weak	3.7	4.8	5.9	7.0	8.1	9.1
	Neutral	4.4	5.5	6.6	7.7	8.8	9.9
	Weak	5.1	6.2	7.3	8.4	9.5	10.6
La Niña	**Moderate**	5.8	6.9	8.0	9.1	10.2	11.3
	Strong	6.5	7.6	8.7	9.8	10.9	12.0

Knowing the Errors Inherent in your Guidance Helps You to Understand Uncertainty in Forecast

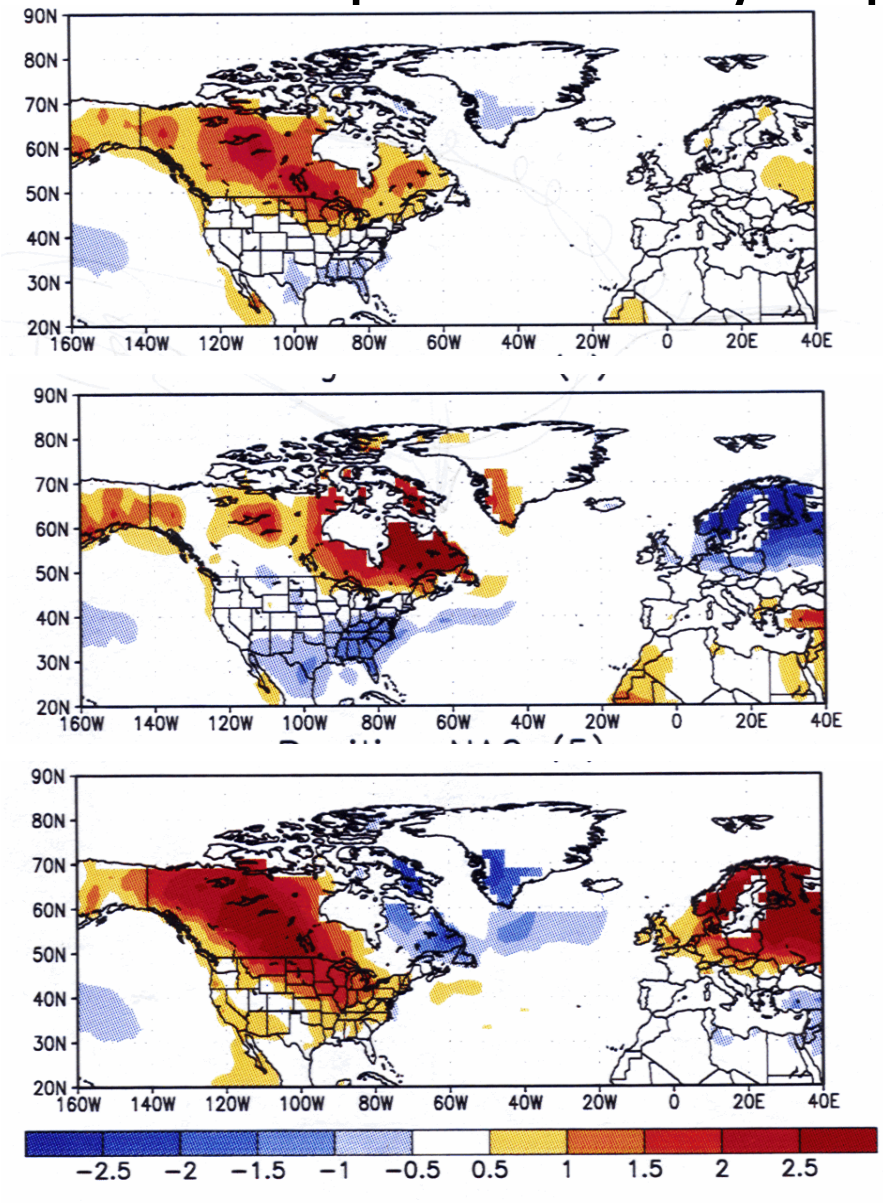


•Regression mean is within one hurricane for nearly ½ of seasons and within 2 hurricanes for 84% of seasons.

•BUT!!! Expect a significant error in the hurricane forecast about 17% (1 in 6) of seasons, even with perfect forecast of climate factors.

Combined Climate Signals

Winter El Niño – NAO Temperature Anomaly Composites



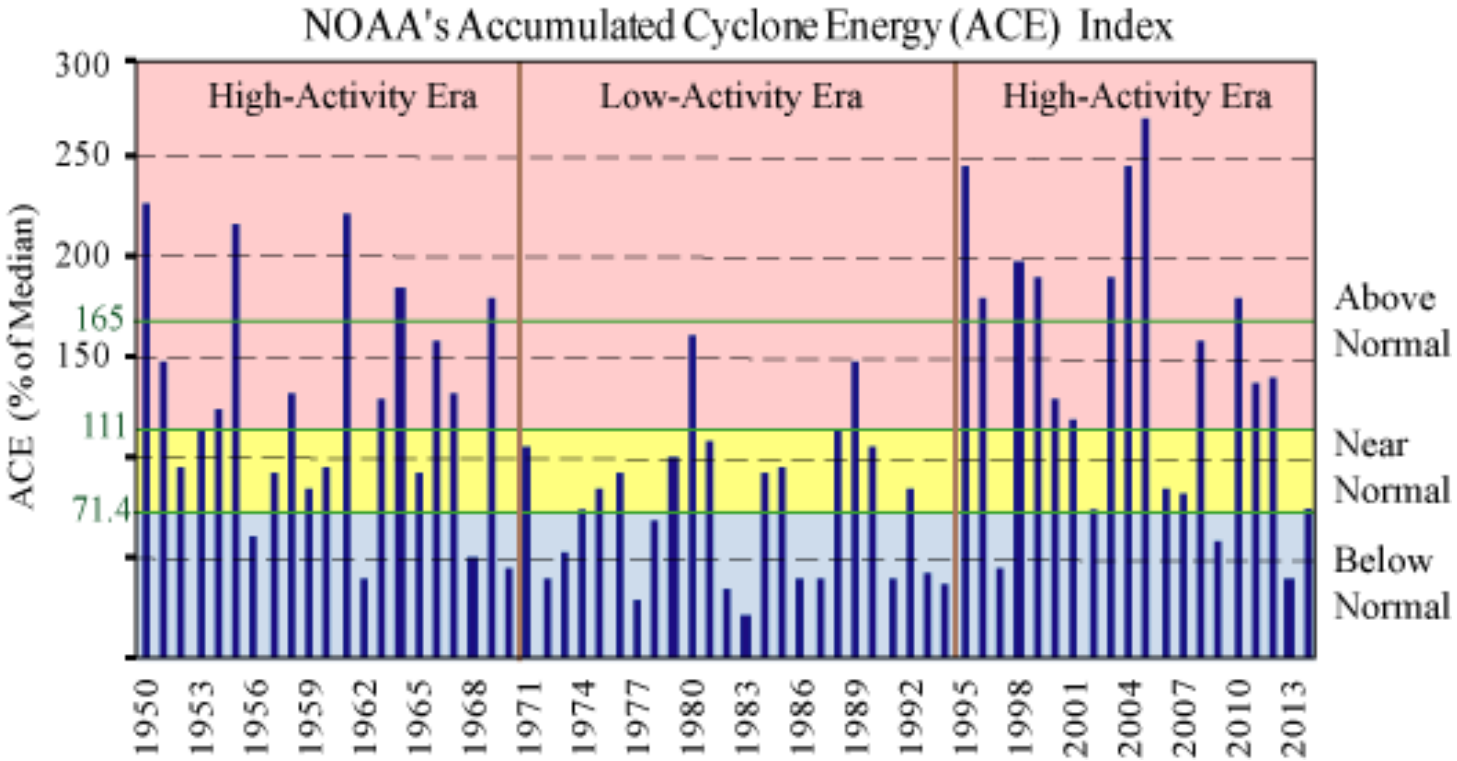
El Niño Only

El Niño and Negative NAO

El Niño and Positive NAO

Multi-Decadal Fluctuations in Atlantic Hurricane Season Strength

Mainly Linked to Atlantic Multi-decadal Oscillation



•ACE index measures overall season strength by accounting for the combined number, intensity, and duration of all tropical storms and hurricanes.

•A high activity era for Atlantic hurricanes began in 1995. These period typically last 25-40 years. The last high-activity era was 1945-1970.

Observed Atlantic Hurricane Season Strength during ENSO Partitioned by Multi-Decadal Signal

Atlantic Hurricane Activity

El Nino

High Activity Decades			Low Activity Decades		
Above Normal	Near Normal	Below Normal	Above Normal	Near Normal	Below Normal
3	4	2	0	2	7

La Nina

High Activity Decades			Low Activity Decades		
Above Normal	Near Normal	Below Normal	Above Normal	Near Normal	Below Normal
6	0	1	1	2	2

Issues Dealing with Combined Climate Impacts

Accounting for combined climate signals can be key to understanding observed climate variability and making a seasonal prediction.

1. Assessing and predicting combined climate impacts
   - Climate patterns can reinforce or counter-act each other
   - Non-linearities in combined climate impacts may not properly be accounted for with regression equations.

2. Take care interpreting regression results based on a single climate factor when the observed signal reflects multiple climate factors.
   - Simple ENSO correlation with seasonal Atlantic hurricane activity yields low correlations (Bove et al.) –Might conclude that ENSO is not a key predictor.

   - Entirely different conclusion emerges when ENSO impacts are examined with respect to the background multi-decadal signal.

3. Climate analogues: Useful and complementary guidance tool when dealing with multiple climate factors.

Climate Analogues Can Be Very Useful

1. Keep the forecaster better focused on past seasons with similar climate conditions to those currently being predicted.

    Hurricanes: e.g., For El Niño during high-activity era, analogues isolate only those seasons

    Extratropics: e.g., For El Niño + positive NAO, only those seasons included in analogue

2. In contrast, with regression, for a given set of climate predictors (e.g., ENSO + NAO), all seasons (all observed combinations of these climate predictors) likely used to develop regression equations.

    Therefore, the regression equation bases its subsequent prediction for one set of climate conditions partly on a different set of conditions:

        e.g., regression forecast for El Niño + positive NAO conditions is partly dependent upon past conditions during La Niña + negative NAO.

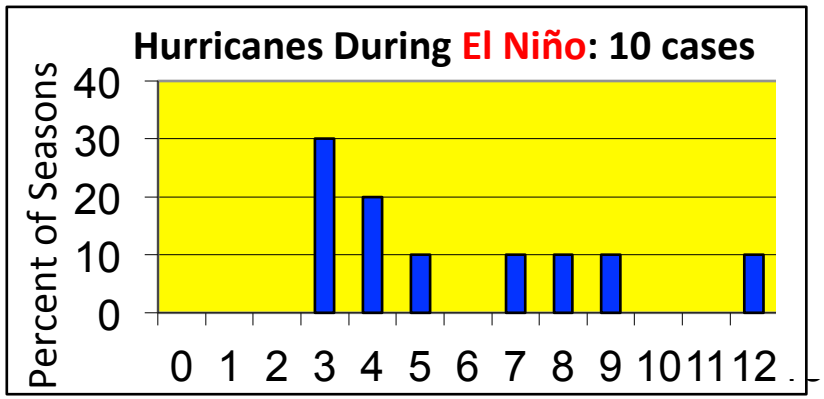
3. Analogue sample size

    Tells forecasters how many seasons actually had climate conditions similar to those being predicted. Help assess "credibility" of both analogue and regression-based guidance.

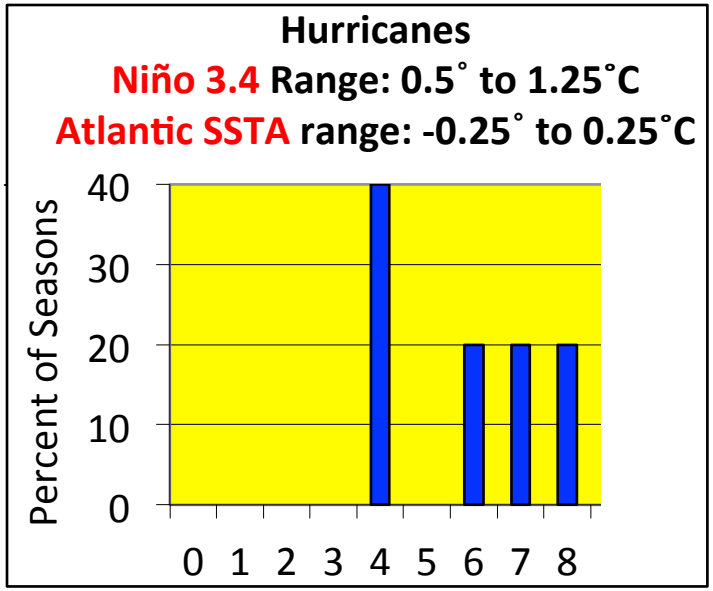
Climate Analogue Guidance Summarized With Bar Graphs

Three Independent Examples: In practice: Calculate using EXCEL.
Background climate signal is Atlantic high-activity era (1950-70, 1994-2014)

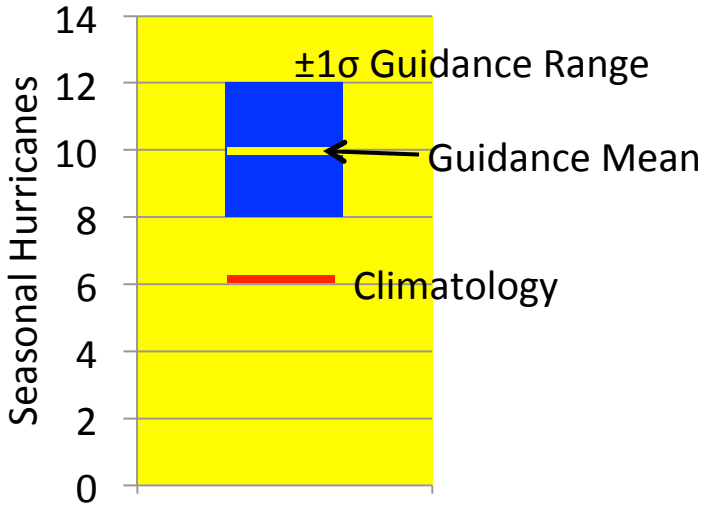
One additional predictor:
El Niño



Two additional predictors:
Niño 3.4 range, Atlantic SST range



Visual Guidance Summary for Forecaster



CFS-V2 Dynamical Ensemble Forecast Guidance for Hurricane Outlook

•Hybrid statistical/ Dynamical Guidance based on CFS- T126 60-member ensemble forecasts

•Regression equations relate historical CFS forecasts of Atlantic SST and vertical wind shear to observed seasonal hurricane activity (Wang et al., 2009)

•Provides forecasters with the observed ranges of activity during past seasons in which model predictions were similar to present.

•Dynamical Guidance based on CFS-T 382 high-resolution climate model (since 2009).

•Direct model forecasts of seasonal activity

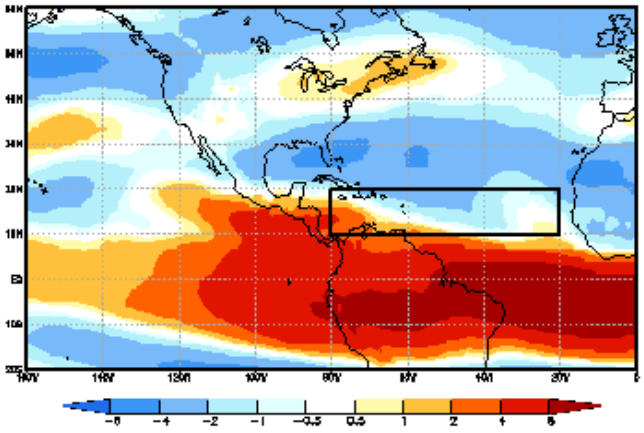
•Tailored guidance for ENSO, ENSO impacts, Atlantic SST, vertical wind shear, etc.

- •Quantify climate predictor strengths
- •Address basic questions, such as: "Will ENSO impacts be strong enough to affect the season?" or "How long will atmospheric response persist after ENSO fades?"

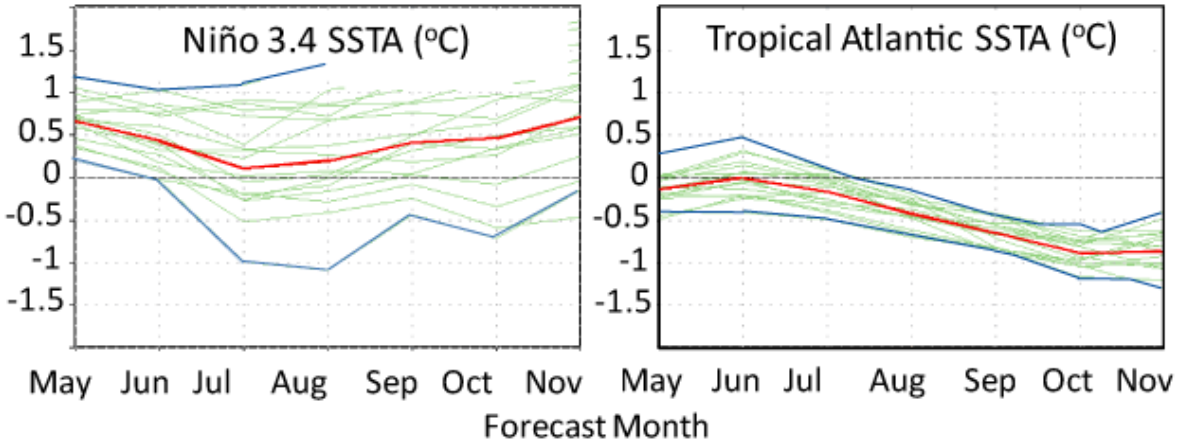
Tailor Your Forecast Guidance

Monthly and Seasonal: Includes forecast maps, indices, individual member results

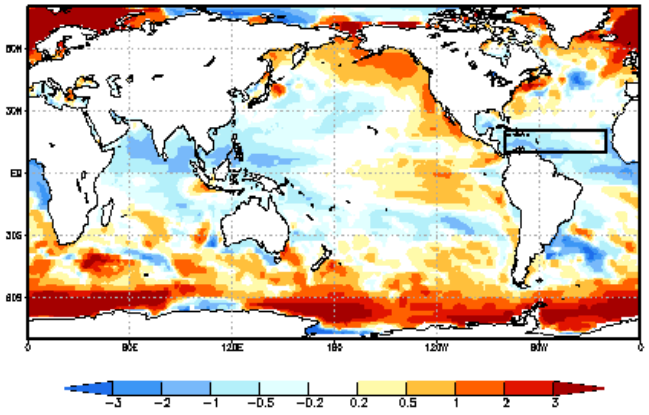
Vertical Wind Shear



Mean Forecast and spread: SST and Wind Shear Indices



SST Anomalies



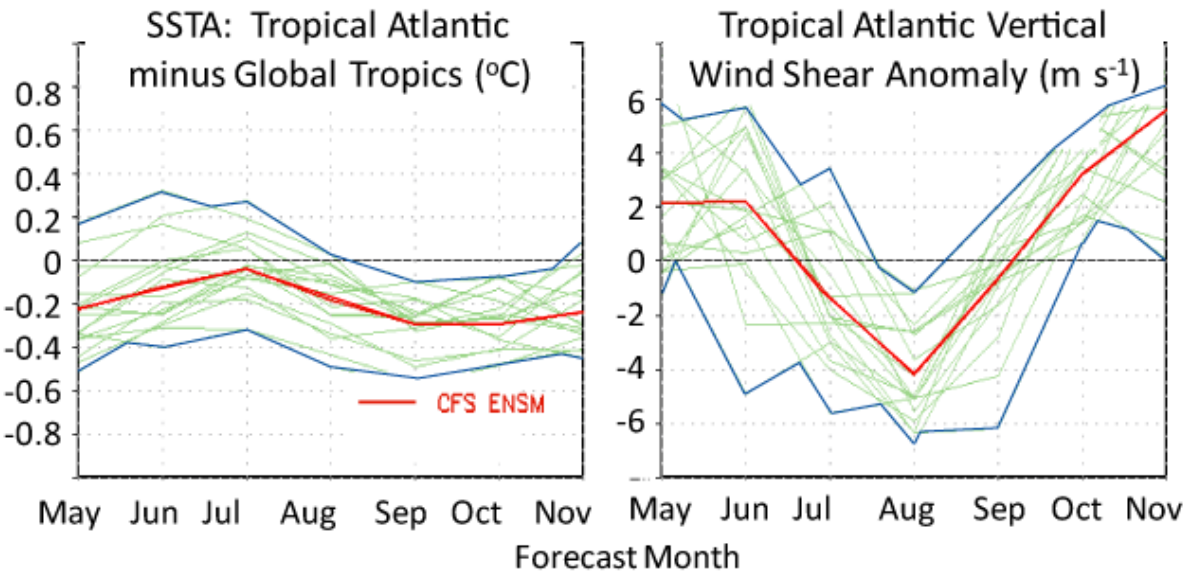


Table Summarizes Guidance Results For Forecaster

Ranges are approximate ±1σ, Mean is shown in parentheses

	Guidance Tool	Named Storms	Hurricanes	Major Hurricanes
Statistical	Regression	9-14 (11.5)	4-7 (5.5)	1-3 (2)
	Analogue: Niño 3.4+SSTA+AMO	8.9-12.3 (10.6)	3-7.4 (5.2)	0.9-3.9 (2.4)
	Analogue: ENSO +SSTA+AMO	7.9-12.1 (10)	3.3-7.1 (5.2)	0.7-3.7 (2.2)
	Analogue: ENSO +AMO	7.9-14.5 (11.2)	2.9-8.7 (5.8)	1.1-4.5 (2.8)
Hybrid: Statistical/ Dynamical	CFS-V2 T126: 1	8-12 (10)	4-6 (5)	2-3 (2.5)
	CFS-V2 T126: 2	10-14 (12)	5-8 (6.5)	2-4 (3)
	CFS-V2 T126: 3	11-15 (13)	5-8 (6.5)	2-4 (3)
	CFS T-382	9-14 (11.5)	2-6 (4)	
Dynamical	GFDL FLOR-FA		2-8 (5)	
	ECMWF	5.9-11.9 (8.9)	2.5-7.3 (4.9)	
	EUROSIP	5.9-11.9 (8.9)		
	UKMET	6-14 (10)	3-7 (5)	1-3 (2)
	Guidance Mean	8.1-13.2 (10.7)	3.3-7.3 (5.3)	1.3-3.6 (2.5)

Summary

Many complementary types of forecast guidance tools may be at your disposal

- Statistical predictors must be independent, predictable, and explain large amounts of variance.

- Skillful dynamical model guidance can be used in many ways.
  - Statistical/ Dynamical hybrid
  - Direct counts of storms
  - Predicting amplitude/ phase of your statistical climate predictors
  - Predict evolving climate conditions, such as atmospheric response to developing ENSO

- Some strategic considerations
  - Develop products to convey guidance results effectively and succinctly
  - Tailor monitoring and guidance products to complement each other
  - Accept that some of your forecasts will be more confident than others.
  - Accurately and meaningfully convey to the public your forecast, your forecast confidence/ uncertainty, and the reasons for your forecast.